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SCIENTISTS AND THEIR PUBLICS

Popularization of Science in the
Nineteenth Century*David M. Knight*

In 1799 the Royal Institution was founded in London, in the wake of various provincial literary and philosophical societies; in 1851, under Prince Albert of Saxe-Coburg's aegis, the Great Exhibition attracted vast crowds to London, yielding profits to buy land in South Kensington for colleges and museums; and in 1900 the Paris Exposition heralded a new century of scientific and technical progress. There were prominent critics, but the wonders of science proved throughout the nineteenth century to be attractive to audiences of the aristocracy and gentry, of working men, and of everybody in between – which was fortunate, because in this world of competing beliefs and interests, of markets and industrial capitalism, those engaged in science needed to arouse the enthusiasm of people who would support them. Popularization started in Europe but was taken up in the United States, in Canada and Australasia, in India and other colonies, and in Japan.¹

We shall focus upon Britain because of its place as the first industrial nation, where cheap books and publications emerged early, and scientific lectures were a feature of intellectual life. Specialization came relatively late to British education, so that until the end of the nineteenth century, university graduates shared to a great extent a common culture. Great Britain contained two nations, the English and the Scots, whose educational histories were very different; and Ireland was another story. Scotland had been, ever since its Calvinist Reformation, a country where education was valued and could be had cheaply in parochial schools and at the universities: It was throughout the eighteenth and nineteenth centuries an exporter of talent, to England, the Continent, and North America. Anglican England saw education as a privilege, and the English were also concerned that too much education would produce overqualified and unemployable people. In the face

¹ D. Kumar, "The Culture of Science and Colonial Culture," *British Journal for the History of Science* (hereafter *BJHS*), 29 (1996), 195–209.

of economic expansion in the Industrial Revolution, this perception gradually changed, and by 1850 the churches were giving an elementary education to most children. But there was a strong tradition of minimum government, of *laissez-faire*.

It was not until 1870 that compulsory state education was introduced, about a century after most other Western European states. At about the same time, provincial universities began to take off, the great stimulus being the Franco-Prussian War of 1870, where the better-educated Prussians defeated a France that had seemed the more formidable military power. Down to that date, the medieval universities of Oxford and Cambridge, with religious tests to exclude non-Anglicans and an ideal of "liberal education," had been dominant, despite a slowly growing challenge from the secular University of London formally chartered in the 1830s. Only at the very end of the century did universities in Great Britain get state funds.

Ireland, not strictly a colony, was throughout the nineteenth century part of the United Kingdom with England and Scotland; but its many problems meant that, like India, it was used as a laboratory for social experiments, notably the "Queen's University," with constituent colleges in different cities and (because of Catholic-Protestant tensions) secular syllabuses. Popular science was featured in Ireland, most notably in lively Dublin, but elementary education, especially in the impoverished countryside, was weak. In years of oppression and famine, countless Irish emigrated to Great Britain, North America, and Australia – usually to humbler jobs than those of the better-educated Scots. Overall, the British experience was unique, but not untypical.

The word "science" in English in 1800 covered all organized knowledge, whereas "arts" included manufacturing and engineering. The word "scientist" was coined by the Cambridge polymath William Whewell (1794–1866) in the 1830s, but it did not come into general use for half a century or so. It came to mean a specialist, a kind of professional, and by the early twentieth century, popularizing was rather despised, bringing no credit within a scientific community oriented toward research and perhaps formal teaching.² Popular writings were (and are) rated even below textbooks by scientific mandarins, and were often written by specialist writers, rather than by eminent scientists. It was different in the nineteenth century, when a scientific reputation – such as that of Humphry Davy (1778–1829), Michael Faraday (1791–1867), T. H. Huxley (1825–1895), Justus von Liebig (1803–1873), or Hermann von Helmholtz (1821–1894) – was enhanced by a capacity to get ideas across in public lectures or in essays.³

² D. M. Knight and H. Kragh, eds., *The Making of the Chemist* (Cambridge: Cambridge University Press, 1998); on textbooks and popular books, see A. Lundgren and B. Bensaude-Vincent, eds., *Communicating Chemistry* (Canton, Mass.: Science History Publications, 2000).

³ D. M. Knight, "Getting Science Across," *BJHS*, 29 (1996), 129–38.

MAKING SCIENCE LOVED

The French Revolution of 1789 was identified not only with youth but also with science, liberating everyone from kingcraft and priestcraft. Terror, the execution of A. L. Lavoisier (1743–1794), war, and the rise of Napoleon led to revulsion from the left-wing dream, especially in Britain; and Joseph Priestley (1733–1804), the great advocate of science and reform, found himself driven into unhappy exile in the United States in the reaction of the 1790s.⁴ France around 1800 led the world in science, but Britain led the world in technology: And just as the French needed men of science to help with the war effort – for instance, to supervise the recasting of church bells as cannon – so in Britain in these hungry years, agriculture as well as industry seemed ripe for scientific improvement.

In 1799 the American Tory Benjamin Thompson (1753–1814), created Count Rumford for his services to Bavaria, succeeded in getting Sir Joseph Banks (1743–1820) and other grandees to back his proposals for a Royal Institution promoting science in London.⁵ In fashionable Albemarle Street, it would have lectures to interest and enthuse the opulent; a laboratory; and also classes associated with exhibitions of machinery to educate artisans. In January 1802, Davy made himself famous with a polished introductory lecture to his course on chemistry. Rumford departed for France with the short-lived Peace of Amiens in that year. Without him, the Royal Institution lost interest in the artisans (and the manufacturers who wanted to keep their machinery and processes secret anyway) and became a center for popular lectures of high caliber delivered to prominent men and women, whose membership fees supported a research laboratory. Throughout the century, here as elsewhere, the performers were male, the audience mixed.

Davy's sometimes colorful rhetoric was suited to his audience: Science depended upon the unequal distribution of property, but its application would bring great benefits to all of Britain's inhabitants.⁶ These were not delusive dreams, like those of alchemical visionaries, his hearers could look forward to a bright day, of which they already beheld the dawn, as men of science (filled with reverence and with awe) penetrated to the bosom of the earth and searched the bottom of the ocean to allay the restlessness of their desires. Davy excited his hearers with reports of his research on tanning, fertilizers, geology, electrochemistry, and acidity; when he lectured in Dublin, there was a black market in tickets. The pattern changed over the years. Faraday started the Christmas Lectures for children, and eminent scientists were also invited to lecture accessibly about their own work, with

⁴ B. Bensaude-Vincent and F. Abbri, eds., *Lavoisier in European Context* (Canton, Mass.: Science History Publications, 1995).

⁵ M. Berman, *Social Change and Scientific Organization* (London: Heinemann, 1978), pp. 1–32.

⁶ D. M. Knight, *Humphry Davy* (Cambridge: Cambridge University Press, 2d ed. 1998), pp. 42–56.

well-contrived demonstration experiments, on Friday evenings during the London season (the winter and spring). But the form of the Institution remained what Davy had made it, and it helped to ensure that science was seen as a part of high culture.

Chemistry, in the wake of Priestley and Lavoisier, promised both intellectual excitement and usefulness. These were picked up by Jane Marcet (1769–1858) in her *Conversations on Chemistry* (1807), written for girls who wanted to know more detail than they could acquire from lectures such as Davy's, and by Samuel Parkes (1761–1825) in his *Chemical Catechism* of the same date, written with boys in mind who would, like the author, work in a chemical trade. Parkes has extensive annotations, some of which amount to encomia upon the wisdom and goodness of the Creator; he was an enthusiastic Unitarian, and especially in Britain and the United States, natural theology was an important part of popular science.⁷ Both these books sold well in successive editions throughout two decades.

THE MARCH OF MIND

In 1807, books were still a luxury item. They were hand printed and expensive, and they came in paper wrappers or in thin boards ready to be taken to a bookbinder (like the young Faraday). Illustrations made from copperplate engravings added to the price. But at this time, wood engraving on the hard end grain of boxwood, as in the popular natural histories of Thomas Bewick (1753–1828), made pictures much cheaper, and they could also (unlike copperplates) be set into the text. Wood engravings were durable, but for long runs, casts, called clichés, were made from them. For bigger pictures, lithographs drawn with wax crayons on stone, which was then wetted and inked with greasy ink, were much cheaper than engravings. From the 1820s, steam presses, stereotyping, wood-pulp paper (chemically bleached), and case bindings of decorated cloth made books much cheaper, better illustrated, and accessible to a mass market.

Although – especially in backward England – many people were still illiterate, there was growing demand for reading matter, and popular science appealed to those with an elementary education. Mechanics' institutes, for artisans like those dropped by the Royal Institution and its imitators, grew up in industrial towns and cities, offering lectures and libraries. Young men, like Faraday when an apprentice or Benjamin Brodie (1783–1862) – a future president of the Royal Society – as a well-connected medical student in London, joined less-formal self-improvement societies where science was prominent.⁸

⁷ F. Kurzer, "Samuel Parkes: Chemist, Author, Reformer," *Annals of Science*, 54 (1997), 431–62.

⁸ F. A. J. L. James, ed., *The Correspondence of Michael Faraday* (London: Institution of Electrical Engineers, 1991–), letters 3–29.

Among the elite, the Cambridge Philosophical Society brought together those in that churchy and conservative university who were interested in advancing mathematics and science. There was no place for women or fashion there, but everywhere, mind or intellect was seen to be on the march: Especially in Parisian and then German and London medical circles, interest in science went with contempt for the "Establishment" and a vision of a meritocratic future.⁹ Parliamentary reform, achieved in part in Britain in 1832 and attempted all over Europe in 1848, went with this program and was associated with the increasing gathering and use of statistics. Inventions, such as Davy's safety lamp for miners, promoted a vision of science as something carried on by men of genius in the metropolis.¹⁰ But while a conservative image of science was available, especially in connection with natural theology – and it would be difficult to overemphasize the importance of religion (especially in the Anglo-Saxon world) in the nineteenth century – there was again by the 1820s and 1830s a radical alternative, modernizing, view.

READ ALL ABOUT IT

Lorenz Crell (1745–1816) helped form the chemical community in eighteenth-century Germany with his journal *Chemische Annalen*, and Lavoisier disseminated his innovations through his *Annales de Chimie*.¹¹ These publications were aimed at scientific practitioners, but in Britain the *Philosophical Magazine* and *Nicholson's Journal* competed for a wider market of those interested in science and perhaps practicing it. Their chatty tone, with reviews and translations, octavo format, and cheaper crowded paper, contrasted with the august volumes published by the Royal Society; and they were commercial propositions, like most popular science. Other journals were published in Edinburgh and in Glasgow, mostly absorbed in the end by the *Philosophical Magazine*, which also formed a model for the *American Journal of Science* of Benjamin Silliman (1779–1864). In natural history, as well as the splendid *Transactions of the Linnean Society*, there were such popular publications as the *Magazine of Natural History*, whose editors encouraged controversy and published articles without the formality of peer review or refereeing. In some cases, as with *The Chemist* of 1824, a journal explicitly appealed to readers excluded from the genteel world; it mocked the pretensions of Davy in its first editorial, recommended cheap forms of apparatus, and paid contributors so that the editors could decide what topics should be covered. Not surprisingly, a journal freighted with such utopian hopes speedily sank.

⁹ A. Desmond, *The Politics of Evolution* (Chicago: University of Chicago Press, 1989); T. L. Alborn, "The Business of Induction," *History of Science*, 34 (1996), 91–121.

¹⁰ J. Golinski, *Science as Public Culture* (Cambridge: Cambridge University Press, 1992), pp. 188–235.

¹¹ M. P. Crosland, *In the Shadow of Lavoisier* (London: British Society for the History of Science, Monograph 9, 1994).

Books were also crucial. The Society for the Diffusion of Useful Knowledge began publishing during the 1820s, galvanizing the older rival Society for the Promotion of Christian Knowledge. In the 1830s Dionysius Lardner (1793–1859) edited a series of little books called *The Cabinet Cyclopedia*. These included a noteworthy *Preliminary Discourse* by John Herschel (1792–1871) – a discussion of scientific method by a great generalist and natural philosopher, who also contributed a *Treatise on Astronomy* – as well as other workmanlike volumes on the various sciences; and a curious set on biology by William Swainson (1809–1883), an advocate for the Quinarian System of classifying organisms in patterns of circles. Among the most successful publishers of information books were the Chambers brothers, William and Robert, in Edinburgh. Robert (1802–1871), in 1844, published anonymously his *Vestiges of the Natural History of Creation*, which became notorious for its evolutionary perspective (from galaxies to humans) and was very widely attacked, and read.¹²

CRYSTAL PALACES

The British Museum, founded in the eighteenth century, contained both beautiful historic artifacts and specimens of natural history, but it did not much welcome the general public and had no formal educational program. In contrast, in revolutionary Paris, the Museum of Natural History became a great center for research and lectures. Exhibitions and museums were a feature of the early nineteenth century, but the former were often of freaks and wonders, and the latter might be professional, like that at the Royal College of Surgeons in London. Learned societies held “conversaziones,” open to members and their guests (including ladies), where objects, experiments, or devices of interest would be on display; but these were again a part of high culture.

As Europe emerged from the hungry forties, the threat of revolution lifting with economic boom, a Great Exhibition of the Works of all Nations in London was planned for 1851. Its most dramatic feature was its building: the Crystal Palace, an enormous glass house (enclosing large trees) put up in Hyde Park. Designed in nine days by Joseph Paxton (1801–1865), a former gardener’s boy, when previous plans had been rejected and with only nine months to go before opening day, it was ready on time – an amazing feat of the railway age, assembled from accurately standardized components brought to the site from distant factories and coordinated there. The hugely successful exhibition drew orderly crowds from all over Britain and overseas to see the latest industrial and aesthetic creations: The only such exhibition so far to make a profit, it made palpable a vision of technical progress.

¹² R. Chambers, *Vestiges*, ed. J. Secord (Chicago: University of Chicago Press, 1995).

While Britain was clearly the leading industrial nation, perceptive commentators (including Henry Cole [1808–1882] and Lyon Playfair [1818–1898], the main organizers) saw the “American System” of mass production and interchangeable parts, and French industrial design, as signs that this pre-eminence was soon to end, and they urged better scientific and technical education. South Kensington, and comparable districts in other great cities like Berlin, developed into centers for both formal education and rational amusement – popular science in museums.¹³

Provincial cities, too, established museums of science, arts, and natural history, sometimes associated with collections of pictures and statuary and often founded in conjunction with a visit by a peripatetic Association for the Advancement of Science. Festivals and exhibitions depend upon ballyhoo and excitement, but museums have permanent collections, and their directors faced the difficult task of balancing the wants of casual visitors and of children with the needs of those undertaking research.

Natural history has always involved important collections of specimens. For museums of physical sciences, the problem became more acute as their exhibits of apparatus or machinery turned with the passage of time into collections of historic importance – hard to display excitingly and unavailable for hands-on play.¹⁴ Visiting museums, which even in Sabbatarian countries like England opened on Sundays, was an important and improving leisure activity in the earnest nineteenth century. Architecturally they came to resemble classical temples dedicated to the Muses, or gothic cathedrals, thus representing classical order or spiritual aspirations. The scientists of the nineteenth century were the heirs, after all, of both the Enlightenment and the Romantic Movement, and a kind of pantheism or nature worship came easily to them. Museums might be associated with libraries and with botanic and zoological gardens dedicated to classifying plants and animals and “acclimatizing” them: transferring merino sheep to Australia, rubber trees to Malaysia, quinine to India, and so on.¹⁵ These benefits of science, at which we sometimes now look askance, were lauded as great improvements to the world.

THE CHURCH SCIENTIFIC

The word “scientist” was coined in a discussion at the Cambridge meeting of the British Association for the Advancement of Science in 1833. Reflecting on his confrontation with Samuel Wilberforce (1805–1873) at

¹³ S. Forgan and G. Gooday, “Constructing South Kensington,” *BJHS*, 29 (1996), 435–68; John R. Davis, *The Great Exhibition* (Stroud, England: Sutton Publishing, 1999).

¹⁴ N. Jardine, J. Secord, and E. C. Spary, *Cultures of Natural History* (Cambridge: Cambridge University Press, 1996), pt. III; A. Wheeler, “Zoological Collections in the Early British Museum,” *Archives of Natural History*, 24 (1997), 89–126.

¹⁵ H. Ritvo, *The Platypus and the Mermaid* (Cambridge, Mass.: Harvard University Press, 1997), pp. 1–50.

the Oxford meeting of 1860, Huxley declared that had a Council of the Church Scientific been called then, it would probably have condemned the Darwinian heresy. He had in mind a meeting of academicians and professors, like the bishops and abbots who attended the Vatican Council of 1869–70; his metaphor is striking, because science did develop rather like a religion, with a clerisy addressing laymen at evangelistic meetings like those of the BAAS.¹⁶ Their presidents and councils came to join those of academies as exponents of the scientific point of view, with access to government and the media.

The British Association did not meet mainly in famous old university cities but all around the British Isles and even in Canada, South Africa, and Australia.¹⁷ It was not the first peripatetic body; its model was from Germany, a constellation of large and small states until the empire was formed in 1870, and even to some extent after that. In the 1820s, Lorenz Oken (1779–1851) organized annual meetings of *Naturforscher*, each year in a different state; after all, there was then no national capital like Paris or London. After some initial unease, the various governments came to welcome the men of science and to compete culturally – in their universities, opera houses, and hosting of such meetings – thus popularizing science for their citizens.

Foreigners were also welcome, and some who went from Britain were much impressed, seeing the opportunity to wrest science from the effete grasp of Londoners and place it in the strong hands of provincials and Dissenters. That was not quite what happened, although sometimes a provincial amateur, such as James Joule (1818–1889), succeeded in getting the eminent to listen to his work on thermodynamics. But the meetings, which began at York in 1831, proved very popular and attracted large crowds of men and women. Cities competed to attract them, offering both to host civic receptions and to build a museum or other scientific institution; and local societies for astronomy, natural history, or other sciences were duly promoted. People could see and hear Faraday and Huxley in the flesh, rather than just read about them; and sometimes there were angry debates – good to watch – which proved that science was not just a dispassionate exercise of reasoning upon facts, as Baconian apologists would have it. The Association, in its turn, became a model for those in the United States, France, and Australasia.¹⁸

The sublime science of astronomy had a large amateur following, though a telescope was a large investment; and for the working class, natural history had the advantages of cheapness, sociability, and fresh air. Field trips, and sessions perhaps in a room above the public bar, went with the identifying of species, at

¹⁶ A. Desmond, *Huxley: Evolution's High Priest* (London: Michael Joseph, 1997); P. White, *Huxley* (Cambridge: Cambridge University Press, forthcoming).

¹⁷ J. Morrell and A. Thackray, *Gentlemen of Science* (Oxford: Clarendon Press, 1981).

¹⁸ S. G. Kohlstedt, *The Formation of the American Scientific Community* (Urbana: University of Illinois Press, 1976); R. MacLeod, ed., *The Commonwealth of Science* (Oxford: Oxford University Press, 1988); R. W. Home, ed., *Australian Science in the Making* (Cambridge: Cambridge University Press, 1988).

which members sometimes became very expert.¹⁹ In both these fields, the gap between the advancement of knowledge and popular science became blurred: Great observatories were restricted by their long-term research programs, and any careful observer with a telescope might see some new planet swim into his ken or, anyway, a comet. In 1820 the Royal Astronomical Society was formed, one of the earliest to be concerned with a physical science; and it flourished, bringing together people with a wide range of interests.

DEEP SPACE AND TIME

By the later eighteenth century, there were no significant believers in the Aristotelian or Ptolemaic world, with the Earth at its center; the vast spaces that had frightened Pascal had come to be accepted. Great reflecting telescopes, like that of William Herschel (1738–1822) at Windsor, the six-foot mirror of Lord Rosse (1800–1867) in Ireland, and then the giant telescopes in the United States, enabled the heavens to be gauged, revealed spiral nebulae, and made our planet feel even smaller. We can see this in popular books: Herschel's *Astronomy* in Lardner's series was a solid but unmathematical read, unrelieved by pictures or invocations of sublimity. J. P. Nichol (1804–1859), on the other hand, published in 1850 a magnificent volume, *The Architecture of the Heavens*, with dark-ground plates of Rosse's discoveries and allegorical illustrations by the Scottish painter David Scott. Robert Ball (1830–1919) of Dublin published in 1886 his *Story of the Heavens*, which was strikingly illustrated; and the writings of Richard Proctor (1837–1888), especially his *Half-hours with a Telescope*, 1868, were beautifully clear and sold extremely well. Proctor left Britain, settling in America, and his output was popular on both sides of the Atlantic. He, and earlier Thomas Dick (1774–1857) in his *Sidereal Heavens* of 1840, argued for a plurality of inhabited worlds.

The idea that God would have put inhabitants only on the Earth, given a vast universe, seemed absurd in the midcentury. Only Whewell emerged as a prominent opponent of the idea, as earlier he had been critical of the "deductive" arrogance of P. S. Laplace (1749–1827) who had no need of God. Whewell feared that (as in *Vestiges*) those who supported plurality would have to deny the special status of mankind so crucial to Christianity, and accept some kind of evolutionary picture in which life emerged from inorganic matter whenever and wherever the time was ripe.

In 1874 the BAAS met in Belfast, and John Tyndall (1820–1893), who was president, took the opportunity not simply to dilate upon science and its possibilities but to present a worldview based upon atomic theory, luminiferous ether, and Darwinism, which among them would account for everything. This caused an immense scandal: His program of wresting the whole of

¹⁹ A. Secord, "Artisan Botany," in Jardine, *Cultures*, pp. 378–93.

cosmology from the clergy was denounced from the pulpits of Belfast and elsewhere. The Belfast Address, an eloquent appeal, it seemed, for a materialistic worldview, was very widely read and commented upon – and disliked by mandarin physicists, such as Lord Kelvin (1824–1907) and Maxwell, who disdained Tyndall's windy popularizing rhetoric.

Astronomical observations were crucial for determining longitude and latitude as the wide-open spaces on Earth were being formally and scientifically explored. Accounts of the voyages and travels of James Cook (1728–1779), Galaup de la Pérouse (1741–1788), P. S. Pallas (1741–1811), Matthew Flinders (1774–1814), Meriwether Lewis (1774–1809) and William Clark (1770–1838), and many others aroused great enthusiasm and sold well; and the objects they brought back swelled collections of natural history and ethnography. Scientific academies in France, Britain, Russia, the United States, and other countries promoted expeditions, so that areas hitherto blank on the map were gradually filled in, coastlines and estuaries charted, and magnetic data collected and mapped – maps and atlases seen as both high-level and popular science. Alexander von Humboldt (1769–1859) introduced thematic maps, which could, for example, represent isotherms, in writing up his Latin American journeys.

Humboldt's books were very popular with armchair travelers, who relished his enthusiastic prose and scientific accuracy, and were an exemplar for the young Charles Darwin (1809–1882).²⁰ His voyage on HMS *Beagle* was one in a great international series of projects, the scientific results of which could be accessibly presented to a public hungry for such things. Such reports often led to missionary activity, which saw a tremendous boom in the nineteenth century, as well as to colonization, by design or sometimes almost by accident, as naval or army officers of European nations assumed powers to pacify and govern those they deemed incapable of governing themselves.²¹ The inhabitants and raw materials of these colonies then interested their new masters, governments, and peoples in Europe, who might also from time to time become excited and angry about injustices committed in their name in distant lands. Colonies were always controversial.

Deep time was also controversial.²² When the eminent surgeon James Parkinson (1755–1824) began publishing his three-volume *Organic Remains of a Former World* in 1804, his frontispiece with Noah's Ark, a rainbow, and some fossil creatures (which had missed the boat and become extinct) was already out of date. His later volumes took into account the researches of Georges Cuvier (1769–1832), who had found a series of faunas beneath the hill at Montmartre, demonstrating that a single flood could not account for extinction. A longer time scale than the seventeenth-century Irish Archbishop Ussher's, in which the world began in 4004 B.C., was required; this, and the

²⁰ J. Browne, *Charles Darwin: Voyaging* (London: Cape, 1995), pp. 236–43.

²¹ M. T. Bravo, "Ethnological Encounters," in Jardine, *Cultures*, pp. 338–57.

²² M. J. S. Rudwick, *Scenes From Deep Time* (Chicago: University of Chicago Press, 1992).

reconstruction of extraordinary fossil creatures, was a source of enormous excitement.

Numerous authors took literalist, liberal, or what we could call agnostic lines, and indeed, one of the functions of the BAAS had been to recognize geologists as scientists and to protect them from supposedly ignorant attacks. The Geological Society of London was famous for its debates, whereas other societies did their best to stifle controversy or keep it behind closed doors. Geology also depended on visual language: Buckland's *Bridgewater Treatise* (1836), demonstrating the goodness and wisdom of God, had pictures of dinosaur tracks and also a handsome colored fold-out plate illustrating the Earth's history through the geological epochs and their characteristic species.²³ Illustrations of extinct animals and plants began to exert their uncanny fascination, as "dragons of the prime that tare each other in their slime" moved the imagination of Alfred Tennyson (1809–1892).

Deep time thus became familiar, but actually thinking in terms of millions of years, like millions of miles, was and is not easy. And the ancestry of man was an explosive topic: Were we just animals? Were some peoples more akin to apes than others? Our dignity and morality were threatened; hairy, stooping, grunting ancestors who had made their way in the struggle for existence did not worry Huxley, whose book *Man's Place in Nature* (1862) was a great feat of popularization – but many were uneasy.²⁴

Huxley found himself locked in controversy with Kelvin over deep time. Darwinians assumed that they could extrapolate from changes in river deltas and exposed coastlines over hundreds of years to the raising and erosion of rock formations over hundreds of millions of years. Kelvin reminded them of the laws of thermodynamics. He computed the age of the Sun, assuming that it was composed of the best-quality coal, and was also getting energy from meteor collisions and gravitational collapse. Making the most favorable assumptions, this led to an age of around a hundred million years. Then he computed the age of the Earth, assuming that it was slowly cooling and applying the mathematics he had picked up from J. B. J. Fourier (1768–1830) on heat flow. This led to a comparable figure; and physicists are always delighted to find two lines of reasoning concordant. Kelvin took some pleasure in reminding brash colleagues like Huxley that physicists could quantify; and his addresses, originally delivered in the late 1860s, were republished in 1894 in his *Popular Lectures and Addresses*. Darwinians could only reply that natural selection must work faster than they had thought, or that something was perhaps wrong with the calculations. When the latter were found to be right, with the discovery of radioactivity, geophysics was set back for a generation.

²³ N. A. Rupke, "The End of History' in the Early Pictures of Geological Time," *History of Science*, 36 (1998), 61–90.

²⁴ A. P. Barr, ed., *Thomas Henry Huxley's Place in Science and Letters* (Athens: University of Georgia Press, 1997).

BEYOND THE FRINGE

The reconstruction of the fossil record was respectable science, and Darwinian evolution became so despite resistance. But right through the nineteenth century, as before and since, there were would-be sciences that often attracted enormous public attention but never achieved the magical status of *scientia*. Indeed, popular science always includes such features, despite the efforts of professionals to purge them away and get the public interested exclusively in those questions with which professors are concerned. In the late eighteenth century, Anton Mesmer (1734–1815) had sent people into trances by passing magnets over them, and animal magnetism, or mesmerism, became a matter of furious controversy and enormous interest first in Vienna and then in Paris. A committee of the French Academy of Sciences, including Benjamin Franklin (1706–1790), established that magnetism was not involved and dismissed the whole phenomenon, but mesmerists continued unabashed throughout the nineteenth century.

Electricity and magnetism were also popular features of the alternative medicine of the early nineteenth century. Established therapies were never very effective (opium, quinine, and alcohol were said to comprise the doctor's armory), and whatever orthodox practitioners might say, desperate diseases demanded desperate remedies.²⁵ Many people were thus attracted (like Darwin) to water cures and to homeopathy, with its principle that minute doses of what caused a disease would cure it. And in the first decades of the nineteenth century, another new science appeared: craniology, or phrenology, the study of the bumps on the head. Starting again in Germany with F. J. Gall (1758–1828), it spread to France, and his disciple J. G. Spurzheim (1776–1832) brought it to Britain. The crucial idea was that the baby's skull was soft and took up the form of the brain beneath. The faculties were located in different regions of the brain, and correlating bulges and concavities in the cranium with strengths and weaknesses in mind would make it possible to read character. Especially in Edinburgh, with its great medical school and educational tradition, the science caught on, and a society and journal were founded.²⁶

The founders hoped that phrenology would speedily be incorporated into the medical curriculum, but a murderer was found to have a big bump of benevolence, and for most, the science became a parlor game. For the widely read educationalist George Combe (1788–1858), however, it was essential for teachers assessing the capabilities of pupils; it was also taught to artists and was popular in mechanics' institutes – the language of "bumps" entered the language, though the science never entered the pantheon.

²⁵ E. Shorter, "Primary Care," in *The Cambridge Illustrated History of Medicine*, ed. R. Porter (Cambridge: Cambridge University Press, 1996), pp. 118–53.

²⁶ R. Cooter, *The Cultural Meaning of Popular Science* (Cambridge: Cambridge University Press, 1984); L. J. Harris, "A Young Man's Critique of an 'Outré' Science: Charles Tennyson's 'Phrenology,'" *Journal for the History of Medicine & Allied Sciences*, 52 (1997), 485–97.

More mysterious were the auras that Karl, Baron von Reichenbach (1788–1869) detected around “sensitive” persons – usually women, and especially pregnant women. These auras also could be seen around magnets and crystals. He was a chemist by training and practice and an expert on meteorites, and his book was translated into English by William Gregory (1803–1858), professor of chemistry in Edinburgh and the translator also of works by Liebig, which we would consider mainstream science. A curious substance called “odyle” was responsible for the manifestations and played a very important role in the economy of the universe.

Nineteenth-century credulity was mocked, for example, by Charles Mackay (1814–1889) in *Extraordinary Popular Delusions* (1841, with a new edition in 1852); but by the 1850s, a new craze had reached Europe from America – spiritualism. In semidarkness, tables rocked, ouija boards spelled out messages, and mediums might levitate or emit ectoplasm taking the form of somebody deceased. Mediums were usually female, and séances provided opportunities (generally unavailable in Victorian England or New England) for holding not merely hands but also arms and legs. These phenomena engaged the interest (intellectual and emotional) of various men of science, especially in Britain and usually after a bereavement. William Crookes (1832–1919) concluded from various experiments that new forces of nature had been revealed, but his paper submitted to the Royal Society’s journal was rejected after a row, and he had to publish it in a more popular periodical.²⁷

In 1882 the Society for Psychical Research was founded under the aegis of Henry Sidgwick (1838–1900), the amazingly well-connected Cambridge philosopher.²⁸ Sidgwick was a notable but reluctant agnostic, who had resigned his post because he could no longer subscribe to orthodox Christianity and hoped that if survival after death could be proved, then religion would be put onto a firmer basis. The Society included two future presidents of the Royal Society, Crookes and J. J. Thomson (1856–1940), and two prime ministers, J. H. Gladstone (1809–1898) and Arthur Balfour (1848–1930), as well as William James (1842–1910) and various bishops and professors. We would have to say that in the years around 1900, psychical research counted as respectable science; and certainly phantasms, hauntings, and mysterious happenings were soberly investigated by empirically minded men and women.

It seemed that more often than could be easily put down to chance, people saw a phantasm of someone they loved who was at that moment in mortal danger, and telepathy sometimes really seemed to happen. After all, radio waves, cathode rays, and x rays were just being investigated; the world was more perplexing than Tyndall had dreamed of in Belfast. Psychical research was a field in which there was nothing deep and recondite, where the common sense of ordinary people might be more appropriate than the learned

²⁷ H. Gay, “Invisible Resource: William Crookes and his Circle of Support,” *BJHS*, 29 (1996), 311–36.

²⁸ J. Oppenheim, *The Other World* (Cambridge: Cambridge University Press, 1985); D. M. Knight, *Science in the Romantic Era* (Aldershot, England: Ashgate Variorum, 1998), pp. 317–24.

ignorance of trained scientists; and thus it was popular. The accounts of phantasms and ghosts give extraordinary glimpses into the lives of our ancestors, their dangerous travels, and their sudden deaths, as well as the assumptions they made about whose testimony was trustworthy and whose was not. Just as extraordinary stories about visitors from outer space, reincarnations, and miracle cures arouse more excitement in our day than orthodox and intellectually demanding science and medicine, so in the nineteenth century the various fringe sciences claimed a giant's share of attention.

A SECOND CULTURE?

Davy, and later Faraday, Huxley, and Tyndall at the Royal Institution, presented science as a part of high culture, where the imagination of the man of genius was kept under control by experiment, rather as the poet's was by the exigencies of meter and rhyme. It was not too arcane; science was trained and organized common sense, as Huxley famously put it – both adjectives being important. Davy wrote poetry, admired in his day, as Erasmus Darwin had done at the end of the eighteenth century, Davy's verse being effusive and romantic rather than didactic. In the early nineteenth century, there was no professional science, and thus no "culture," no scientific community with its shared education and values to set against the literary culture, as C. P. Snow (1905–1980) did in his controversial lecture on "the two cultures" amid educational debates in the 1950s.

For Matthew Arnold (1822–1888), Victorian aristocrats were "barbarians," hunting and fighting, while those involved in industry and commerce were smug "philistines," uninterested in cultural activity unless it was safely domesticated. As industrial revolutions opened new avenues of social mobility, those who lacked the familiarity with literature, music, painting, and sculpture that went with inherited wealth sought in science – especially astronomy and natural history – something beyond mere business. Snow found that in the mid-twentieth century, scientists found solace in music rather than literature or the visual arts. If that was true then, or is true today, it was not so in the nineteenth century. Helmholtz wrote a famous work, *Sensations of Tone*, about the physics of music, which was accessible to musicians and remains a classic; but he also studied and wrote popularly on color and our perception of it.²⁹ Chemists like Davy worked on pigments ancient and modern, while physicists like John Herschel and Maxwell wrote poetry.

Science was prominent in some nineteenth-century poetry, most notably Tennyson's *In Memoriam*, which gave us the haunting phrase "nature red in tooth and claw" and memorable stanzas about geological time. Tennyson had picked up his knowledge from reading Lyell and *Vestiges* – his readers would have become aware of current scientific thinking, partly as a threat, in

²⁹ D. Cahan, ed., *Hermann von Helmholtz* (Berkeley: University of California Press, 1993).

reading the poem.³⁰ Huxley considered *In Memoriam* an example of scientific method and admired Tennyson's other writings also.

Science is similarly to be found in women's writing: in *Frankenstein* by Mary Shelley (1797–1851) and in *Middlemarch* by George Eliot (Marianne Evans, 1819–1880), who had previously translated, from the German, rationalistic works by David Strauss and Ludwig Feuerbach. Mary (Mrs. Humphry) Ward's (1851–1920) best-selling novel about religious doubt, *Robert Elsmere*, 1888, given away to promote soap in what must have been a very literate America, contains surprisingly little science. The hero's faith is chiefly undermined by historic doubts, rather than concern about miracles, but science is in the background, and the book created an enormous furor following upon a review of it by Gladstone.³¹

Reviews were prominent in the intellectual life of the nineteenth century.³² Indeed, they were the main humanistic journals until historical, literary, and philosophical publications on the lines of scientific periodicals appeared late in the century. In Continental Europe, eighteenth-century reviews made thought in one language accessible in another. In Britain, the *Monthly Review* consisted of book reviews that were essentially paraphrases or lengthy quotations – the object was to convey the writer's style and conclusions, and critical appraisal was generally secondary. The *Edinburgh Review* changed all that: Its articles, written from a Whig viewpoint, were trenchant commentaries of twenty or thirty closely printed pages on books of all kinds, including scientific works, monographs, textbooks, and even issues of journals. They are what we would call essay-reviews, written for the well-informed but unspecialized reader; and sometimes the essayist would go off on a tangent, so that the book reviewed became a point of departure, as with Henry Holland (1788–1873) discussing "Modern Chemistry" in the rival *Quarterly Review* in 1847. The *Quarterly* was Tory; the *Westminster*, radical; and the *North British* represented the Free Presbyterian Church of Scotland.

Whatever their political or religious stance (and the two generally went together in Britain), these quarterlies would normally have at least one essay in every issue concerned with science or technology. Contributions were anonymous, and so editors could amend them (though they did this at their peril if they blue-penciled an eminent author), and reviewers could speak their minds in the small intellectual world of the day – when authorship (as with Samuel Wilberforce's essay on Darwin) was in fact often an open secret. They were an expression of high culture, often outspoken in criticism when dealing with literature (attacks on William Wordsworth and John Keats are

³⁰ A. J. Meadows, "Tennyson and Nineteenth-Century Science," *Notes and Records of the Royal Society*, 46 (1993), 111–18.

³¹ J. Sutherland, *Mrs Humphry Ward* (Oxford: Oxford University Press, 1990).

³² J. Shattuck and M. Wolff, eds., *The Victorian Periodical Press: Samplings and Soundings* (Leicester, England: Leicester University Press, 1982).

notorious) or religion, but usually respectful about science, seeing a duty in getting the latest ideas across without jargon or excessive detail.

The question was whether this was enough by the 1870s. In his monthly *Nineteenth Century* from 1877, James Knowles (1831–1908) provoked lively debates with signed articles; among his coups was bringing Huxley and Gladstone into public conflict about science.³³ But in 1864, Crookes played an important part in launching the *Quarterly Journal of Science*. This was to be a kind of review, devoted to science and appearing at a time when specialization meant that those active in one science did not necessarily understand what those in other fields were up to. They thus needed up-to-date popular writing, just as much as those outside the scientific community. But this journal, which went monthly in 1879, was superseded by weeklies, such as Crookes's *Chemical News* and *Nature*, edited by Norman Lockyer (1836–1920), which brought prestige, but not money, to Macmillan, its London publisher. By the end of the century, one can speak of a scientific "culture."

TALKING DOWN

Textbooks and works of popular science were written by notable researchers, such as Huxley, Tyndall, and Kelvin, but increasingly such writing came to be seen as a distinct activity with its own particular skills. Huxley hoped in his popular lectures to convey "scientific method," and with it, in his case, an agnostic attitude toward anything dogmatic or metaphysical.³⁴ In his wake, scientism – the idea that only empirical scientific explanations are genuine – gained ground, especially among popular writers, to the distaste of fastidious prominent scientists, who often then (as since) retained or found religious belief and metaphysical interests. Thus, Balfour Stewart (1828–1887) and P. G. Tait (1831–1901) popularized thermodynamics in their *Unseen Universe*, which was also a work of religious apologetics, while Balfour's philosophical writings were designed to establish that science, like everything else, rested upon belief.

Darwin's cousin Francis Galton (1822–1911) studied the careers and relationships of scientists (and other eminent men) as a contribution to the long-running "nature or nurture" debate. He, as an adherent of "scientific naturalism," also investigated the efficacy of prayer, comparing the life spans of the royal family, often prayed for in church, with those of aristocrats; there was no difference. Popular writers, such as Jules Verne (1828–1905) in France, revived the genre of science fiction to present a picture of high adventure amid technical progress.

³³ P. Metcalf, *James Knowles* (Oxford: Clarendon Press, 1980), pp. 274–351.

³⁴ B. Lightman, *The Origins of Agnosticism* (Baltimore: Johns Hopkins University Press, 1987), pp. 7–15.

Faith in science was on the increase as death rates fell, with scientific medicine at last making a real impact and religion seeming to be fuddy-duddy and old-fashioned. The public turned to journals, including the *Popular Science Monthly*, the *Scientific American*, the *English Mechanic*, and *Science Gossip*.³⁵ Self-improvement and an interest in nature were now also expressed in magazines with a technological bent, accompanied by advertisements. Optimism was everywhere.

Thermodynamics, however, was delivering another message: that the Sun could not burn forever, and that the Earth was steadily cooling down. In a few tens of millions of years, according to Kelvin's calculations, life here will have become impossible, and all the achievements of mankind will have turned to dust.³⁶ This idea was taken up by H. G. Wells (1866–1946) in his novel *The Time Machine*, in which the time traveler going forward finds that the human race has evolved into two species (one from effete aristocrats, the other from ferocious proletarians), and then further on that all intelligent life has disappeared from the cooling Earth. A deep pessimism about science and technology similarly permeates the novels of Thomas Hardy (1840–1928).

A fascination with degeneration and degradation was thus allied with the sciences in the popular mind, leading to widespread anxiety about whether disorder in society, as in the physical world, was inevitably increasing. Darwinian development, too, was not necessarily progressive, and for Cesare Lombroso (1836–1909) and his many popular echoes, criminals and the unintelligent represented throwbacks to primitive ancestors. All the gains of civilization might be lost in atavism. Galton was a pioneer of eugenics, hoping to promote good breeding by ensuring that the more intelligent had larger families than the foolish and improvident.³⁷ Such ideas, commonplace in the opening years of the twentieth century, were acted upon by governments, democratic as well as dictatorial, who sterilized the unfit: Popular science could issue in policy.

SIGNS AND WONDERS

By 1800 newspapers had been around for a long time, but the coming of cheap paper and steam presses, and the lifting of "the tax on knowledge" to which they had been subject, meant that Britain was early in the field of mass-circulation papers. The building of the railway system, and the electric telegraph that developed hand in hand with it, meant that national newspapers carrying up-to-date international material became ever more

³⁵ R. Barton, "The Purposes of Science and the Purposes of Popularization," *Annals of Science*, 55 (1998), 1–33.

³⁶ C. Smith and N. Wise, *Energy and Empire* (Cambridge: Cambridge University Press, 1989), pp. 524–645.

³⁷ J. Pickstone, "Medicine, Society and the State," in Porter, *Medicine*, pp. 304–41.

important. What newspapers have always wanted were stories, though they were prepared to carry rather dull information as well. Sometimes the sciences provided excitement, although the most famous case was a hoax: John Herschel had gone to South Africa in 1833–8 to observe the southern stars, and a New York newspaper reported that he had seen inhabitants on the moon.

This duly boosted sales, but usually newspapers had to rely upon events such as the meetings of the British Association or major exhibitions to get something newsworthy. Even so, the debate between Huxley and Bishop Samuel Wilberforce at Oxford in 1860 was not properly reported because it happened on a Saturday afternoon when the main BAAS meeting was over and the reporters had gone home. Accounts of lectures, the opening of new buildings, real or imagined medical advances, and obituaries of men of science occupied an important place in newspapers. Huxley's review of the *Origin of Species* appeared in the London *Times* and was important in making the book known, and Faraday's letter to the *Times* exposing table turning was another celebrated landmark. The more popular newspapers usually carried less science. Armaments and innovations therein, the ironclad warship, the breech-loading gun, gun-cotton, and other explosives duly got into the news, as also did pollution from sewage and chemical works and accounts of vivisections. Popular stories about science were not all positive.

As well as newspapers there were magazines. *Punch*, with its lighthearted editorial matter and its cartoons, did get across aspects of science, especially Darwinism and our relationship with monkeys. The caricatures of the eminent (including leaders of science) in *Vanity Fair* were and are much prized; they were kinder than the caricatures of Priestley, Banks, Davy, and others around 1800. Wood engraving, lithography, and photography (often combined) meant that pictures became increasingly prominent; the slabs of text characteristic of newspapers and magazines in the early years of the century gave way to a livelier look. And science got in because of its importance, and sometimes its aesthetic quality.³⁸

Science in the 1790s was harmless, perhaps useful, its image somewhat tarnished by memories of projectors and by association with revolution. By 1900 it was formidable, playing a major part in education and in economic life, for the equation of technology with applied science was accepted by readers of popular science. At the Paris Exposition of 1900, electricity, now providing the energy that was recently proved to underlie matter, was the great novelty.³⁹ Crowds flocked again to innovations, hoping that science would usher in a new century of peace and progress. The wonders of science were

³⁸ L. P. Williams, *Album of Science: the Nineteenth Century* (New York: Scribner's, 1978).

³⁹ R. Brain, *Going to the Fair* (Cambridge: Whipple Museum, 1993); R. Fox, "Thomas Edison's Parisian Campaign," *Annals of Science*, 53 (1996), 157–93.

there as before (there were even tribesmen in exotic villages), but brought up to date as the world hustled down the ringing grooves of change. It was a splendid spectacle; the nineteenth century had been an age of science, and the twentieth would be even more so. As we know, first the *Titanic* disaster revealed the dangers of hubris, and then between 1914 and 1918, in World War I ("the chemists' war"), developments in aircraft and poisonous gas proved both the alarming power of science and society's need for it.